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The Microcab Vianova

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HYDROGEN IS COMING!

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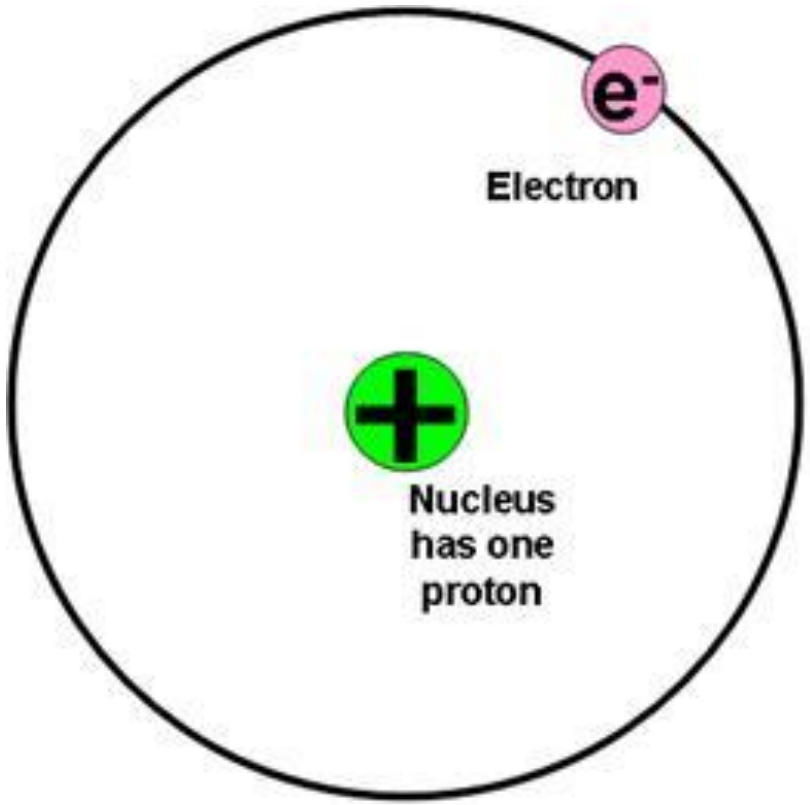
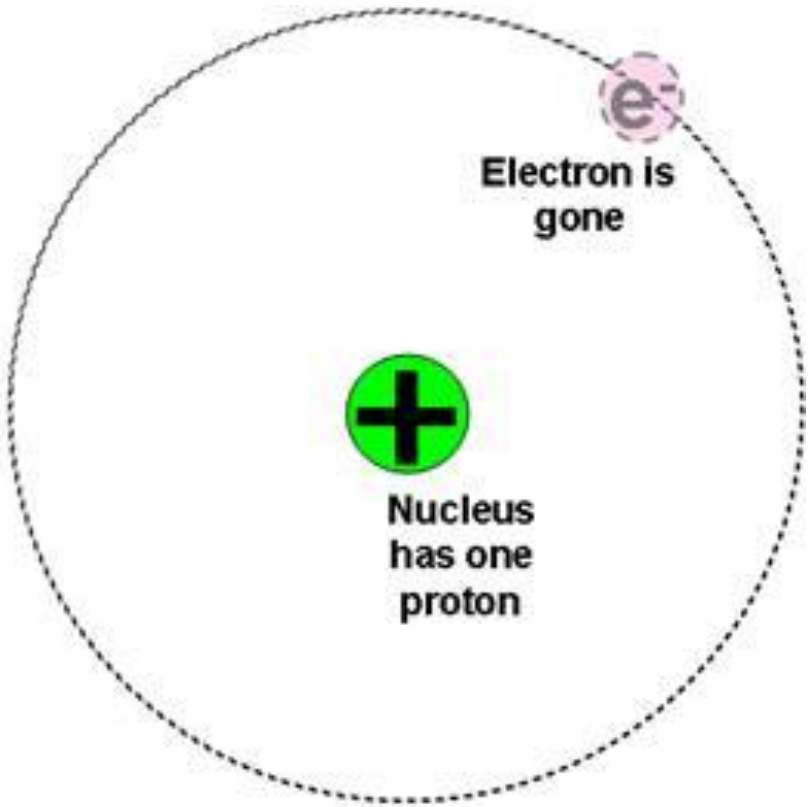


Hydrogen atom = 1 p^+ and 1e^-
"H"



Hydrogen ion = 1 p^+ only
"H^+"

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Emissions from Fuel Cell create water

$$OH^- + H^+ \rightarrow H_2O$$

hydroxide ion hydrogen ion

Opposite is Electrolysis

$$H_2O \rightarrow OH^- + H^+$$

hydroxide ion hydrogen ion

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A BRIEF HISTORY OF FUEL CELLS

- Discovered - Sir William Grove in 1838
- First Commercial use Francis Thomas Bacon in 1932
- First well-known use Bacon cells by NASA for satellites and space capsules since 1960s
- Main Company now Ballard (since late 70s)

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MODERN FUEL CELLS

- Fuel cells consist of an anode, a cathode, and an electrolyte
- Main type is proton exchange membrane (PEM) fuel cells but are also others
- PEMs use expensive metals at present mainly platinum
- The energy efficiency of a fuel cell is generally between 40–60%, but efficiencies of up to 85% can be obtained.

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ENERGY REVOLUTIONS

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REVOLUTION 1

- RENEWABLE ENERGY
- WORLDWIDE WIND/SOLAR

REVOLUTION 2

- HYDROGEN
- WORLDWIDE HYDROGEN

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REVOLUTION 1

RENEWABLE ENERGY

- UK - Renewables produced 33% of the UK's electricity production in 2018 (DUKES, 2019)
- California - State targets are 60% renewable by 2030 and 100% by 2045
- Worldwide - Solar power 35% of all new power generating capacity in 2017 and will be cheaper than fossil fuels within the next decade
- 72% of the $10.2 trillion spent on new power generation worldwide to 2040 will be invested in new wind and solar plants (Bloomberg New Energy Finance)
- Renewables can guarantee energy security at any scale as it can be produced locally (or even domestically)

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REVOLUTION 2

HYDROGEN

Can be and is being…

- Produced efficiently from renewable sources
- Stored and distributed as hydrogen for FCEVs
- Stored and distributed for re-conversion to electricity in times of under-supply for weather dependent renewable energies
- Distributed through existing gas pipeline networks as a supplement to natural gas supplies or for recovery downstream
- Produced and stored on a large, medium and small scale
  (including domestically)

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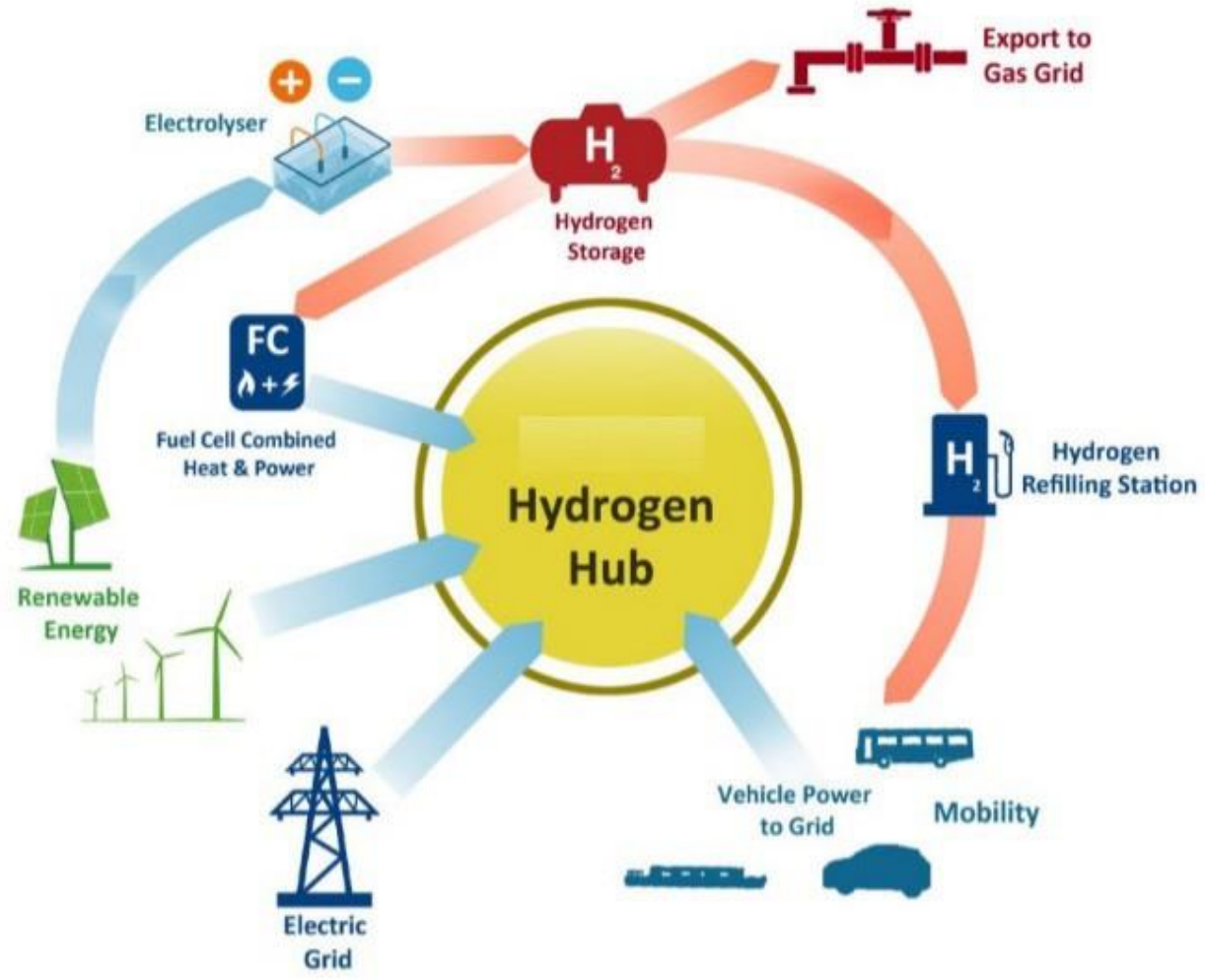
THE HYDROGEN ECONOMY



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IS ANY OF THIS HAPPENING?

ARE RENEWABLES HAPPENING?

MIT article on Renewable energy, 24/12/19
The cost of large wind and solar farms dropped by 70% and nearly 90%, respectively. Meanwhile, renewable-power plants around the world are producing four times more electricity than they did 10 years ago.
https://www.technologyreview.com/s/614917/our-pathetically-slow-shift-to-clean-energy-in-five-charts/

3 Predictions for US Renewables and Storage Markets in 2025, 30/12/19
The U.S. has deployed more energy storage since the second half of 2018 than the total of all prior years. In 2020 alone, we expect total storage deployed to double again. By 2025, we will be well on our way to the clean energy future that we need.
https://www.greentechmedia.com/articles/read/3-predictions-for-the-us-renewables-and-storage-markets-in-2025

US has only one offshore wind energy farm, but a $70 billion market is on the way, 15/12/19
KEY POINTS –
- Offshore wind has the potential to generate more than 2,000 GW of capacity per year (7200 TWh/yr)— nearly double the nation's current electricity use, according to the DOE.
- By one estimate, there will be a $70 billion offshore wind business pipeline in the U.S. by 2030.

https://www.cnbc.com/2019/12/13/us-has-only-one-offshore-wind-farm-but-thats-about-to-change.html

Fossil fuels fall to record low in Britains energy mix data shows, 19/12/19

Government figures showed the UK relied on renewables, such as wind and solar, for 38.9% of its electricity in the third quarter of this year, up from one-third in the same period in 2018… Renewable energy moved narrowly ahead of gas-fired power, which made up 38.8% of the electricity mix, to emerge as the UK's biggest source of power.

https://www.theguardian.com/environment/2019/dec/19/fossil-fuels-fall-to-record-low-in-britains-energy-mix-data-shows

Worldwide RENEWABLE CAPACITY STATISTICS 2019 IRENA

https://www.irena.org/publications/2019/Mar/Renewable-Capacity-Statistics-2019

Renewables On The Rise In The Mining Industry, 26/12/19

In a recent report, consultancy firm THEnergy stated that 2019 saw significant growth in the number of mining companies materially committing to develop onsite renewable energy projects.

https://oilprice.com/Alternative-Energy/Renewable-Energy/Renewables-On-The-Rise-In-The-Mining-Industry.html

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WHAT IS REAL?

Offshore wind power price plunges by a third in a year: BNEF, 22/10/19

Larger turbines drive 32% offshore decline as equipment costs drive onshore wind and PV prices down, says analyst. New-build offshore wind has seen the fastest cost fall of any renewable energy source, according to BNEF's second-half 2019 global benchmark price of **$78/MWh** – down 32% on the same stage in 2018 and 12% from the first half of the year.

Wind energy is the cheapest source of electricity generation, 29/3/19

Wind energy is today the cheapest source of electricity generation in majority of places in the world. Unsubsidized onshore wind energy is cheaper than any other energy source, including conventional power generation sources such as coal and gas.

According to the Bloomberg New Energy Finance data, the levelised cost of electricity (LCOE) of onshore wind in Europe ranges from **$58 (€50) to $76 (€65)/MWh** in H1 2018.

https://windeurope.org/policy/topics/economics/

Largest US Solar Power Plant Will Be Built On Public Land. Is That A Problem?, 7/1/20

The $1 billion Gemini project is being developed by Quinbrook Infrastructure Partners and Arevia Power, and will include large scale storage batteries, although few specs about the storage component of the project have been released at this point. It will supply power to NV Energy, Nevada's largest public utility. NV Energy has signed a 25-year power purchase agreement with the developers and has agreed to pay **$38.44/MWh** for electricity during that period.

https://cleantechnica.com/2020/01/07/largest-us-solar-power-plant-will-be-built-on-public-land-is-that-a-problem/

Hinkley Point C cost rises by nearly 15%, 25/9/19

Consisting of two Areva-designed European Pressurised Reactors, it will be the first new nuclear power station to be built in the UK in almost 20 years and will provide about 7% of the country's electricity….The CfD - the ratepayer-backed guaranteed price for electricity generated by Hinkley Point C - was originally agreed in October 2013 and guarantees the plant will get **GBP92.50/MWh** for its first 35 years of operation.

http://world-nuclear-news.org/Articles/Hinkley-Point-C-cost-rises-by-nearly-15

AT EXCHANGE RATE ON 12/1/20 £92.50/MWH = $120.85/MWH = 2 X WIND = 3 X SOLAR

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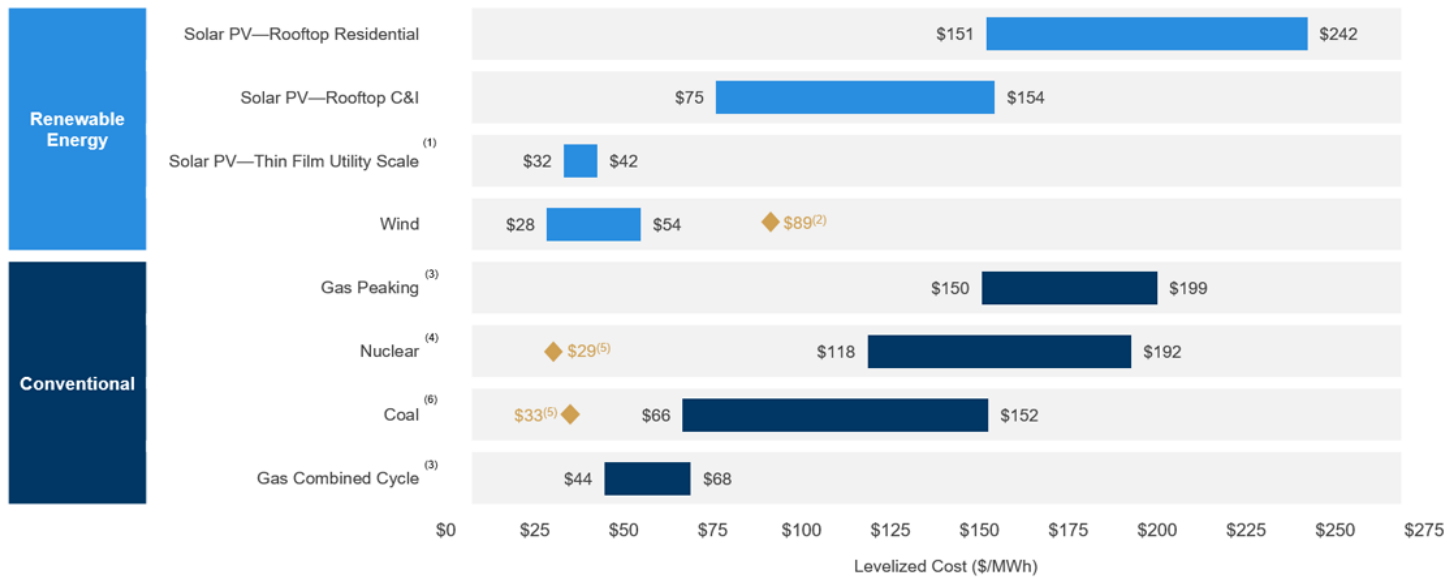
Levelized Cost of Energy Comparison—Unsubsidized Analysis

Selected renewable energy generation technologies are cost-competitive with conventional generation technologies under certain circumstances



Source: *Lazard estimates.*
Note: Here and throughout this presentation, unless otherwise indicated, the analysis assumes 60% debt at 8% interest rate and 40% equity at 12% cost. Please see page titled "Levelized Cost of Energy Comparison—Sensitivity to Cost of Capital" for cost of capital sensitivities. These results are not intended to represent any particular geography. Please see page titled "Solar PV versus Gas Peaking and Wind versus CCGT—Global Markets" for regional sensitives to selected technologies.
(1) Unless otherwise indicated herein, the low end represents a single-axis tracking system and the high end represents a fixed-tilt system.
(2) Represents the estimated implied midpoint of the LCOE of offshore wind, assuming a capital cost range of approximately $2.33 – $3.53 per watt.
(3) The fuel cost assumption for Lazard's global, unsubsidized analysis for gas-fired generation resources is $3.45/MMBTU.
(4) Unless otherwise indicated, the analysis herein does not reflect decommissioning costs, ongoing maintenance-related capital expenditures or the potential economic impacts of federal loan guarantees or other subsidies.
(5) Represents the midpoint of the marginal cost of operating coal and nuclear facilities, inclusive of decommissioning costs for nuclear facilities. Analysis assumes that the salvage value for a decommissioned coal plant is equivalent to its decommissioning and site restoration costs. Inputs are derived from a benchmark of operating coal and nuclear assets across the U.S. Capacity factors, fuel and variable and fixed operating expenses are based on upper and lower quartile estimates derived from Lazard's research. Please see page titled "Levelized Cost of Energy Comparison—Renewable Energy versus Marginal Cost of Selected Existing Conventional Generation" for additional details.
(6) High end incorporates 90% carbon capture and compression. Does not include cost of transportation and storage.

Lazard's 2019 annual Levelized Cost of Energy Analysis (LCOE 13.0)
https://www.lazard.com/perspective/lcoe2019/

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IS HYDROGEN HAPPENING?

Green Hydrogen the potential energy transition gamechanger, IRENA Ministerial Round Table, 11/1/20

https://fuelcellsworks.com/news/green-hydrogen-the-potential-energy-transition-gamechanger/

Japan, EU & US-agree-to-hydrogen-and-fuel-cells-partnership, 11/12/19

https://fuelcellsworks.com/news/japan-e-u-and-u-s-agree-to-hydrogen-and-fuel-cells-partnership/

Re-imagining Scotland: Can hydrogen fuel unlock our future energy potential?, 15/9/19

Scotland is leading the way with gas touted as cleaner alternative to petrol and diesel.

https://www.insider.co.uk/special-reports/can-hydrogen-fuel-unlock-scotlands-20070965

NWHA Welcomes Halton Borough Council, 5/12/19

Halton Borough Council has been named the first local authority to join the North West Hydrogen Alliance, an organisation working to develop the North West as the UK's primary hydrogen economy, 5/12/19

https://www.h2-view.com/story/nwha-welcomes-halton-borough-council/

Aramco To Build First Hydrogen Fueling Station, Saudi Arabia, 25/1/19

https://oilprice.com/Latest-Energy-News/World-News/Aramco-To-Build-First-Hydrogen-Fueling-Station.html

Germany's 79th hydrogen station opens, 19/12/19

https://www.h2-view.com/story/germanys-79th-hydrogen-station-opens/?fbclid=IwAR1jfsClalKfLE8d3h1cDMjFd12rz7tFDkjdZpV690SbP0njtd7h5Wy6XGg

Ports Enter Partnership on Hydrogen--Groningen Seaports, Port of Amsterdam & Port of Den Helder entering into a partnership & will position themselves under the name Hydroports to become the hydrogen hub of Europe, 16/12/19

https://fuelcellsworks.com/news/ports-enter-partnership-on-hydrogen/?fbclid=IwAR0QM5J9UrR7RQuhiGAS_REuCZnVUnyOtTecrbOv_DbSOCO4MJyaCEuQ9Hw

Japan launches first liquid hydrogen carrier ship, 11/12/19

https://www.ft.com/content/8ae16d5e-1bd4-11ea-97df-cc63de1d73f4?fbclid=IwAR1bOSwGMDPuGbLYhrz-oYzPLZ_3aMIdyZgUu8FB4GrQNMpfTzCuzTlQl4c

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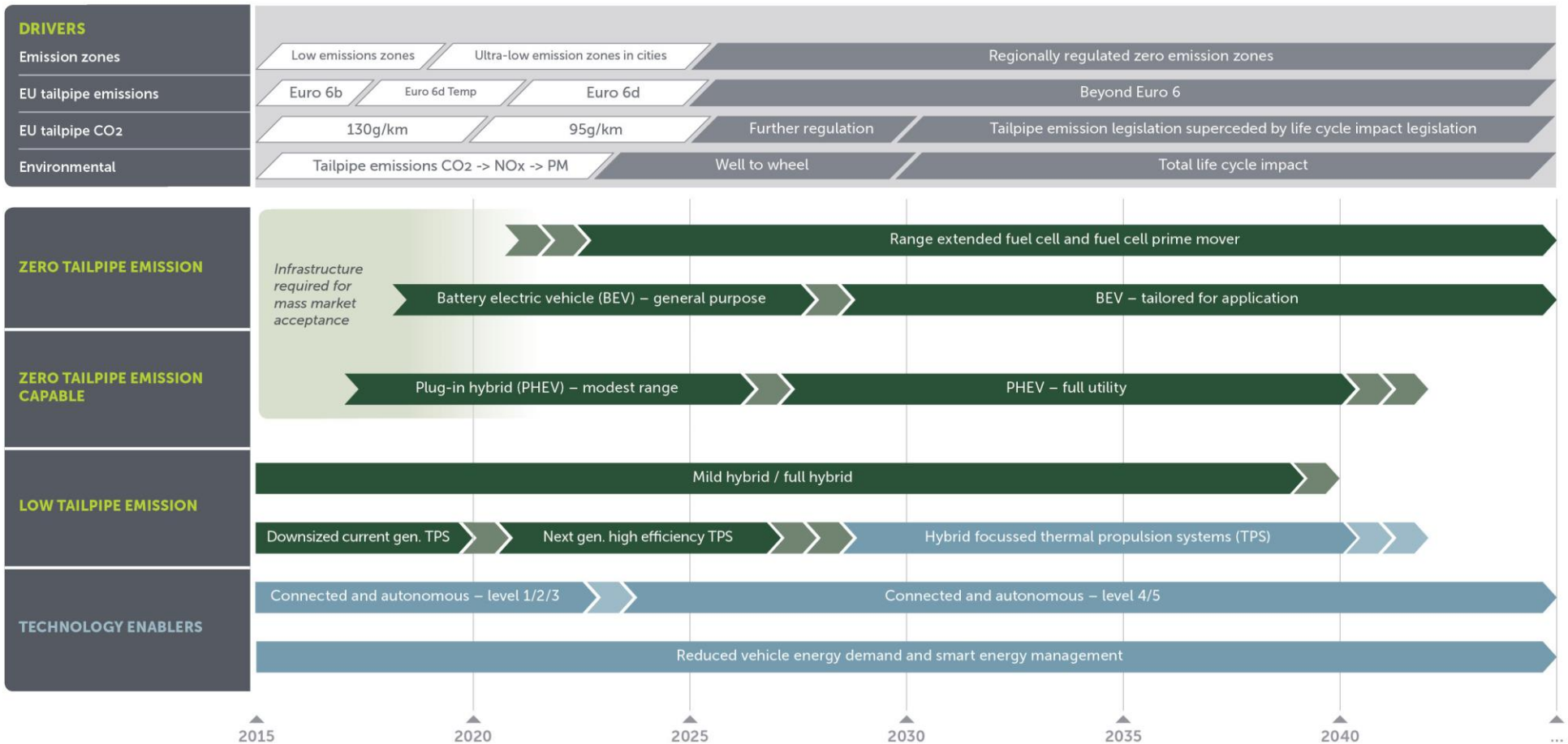
PRODUCT ROADMAP 2017: **PASSENGER CAR**

Roadmap developed by the Automotive Council and the Advanced Propulsion Centre

automotive council UK

ADVANCED PROPULSION CENTRE



Driver set | Driver predicted

Solid bar represents >1% global marked adoption and is preceded by significant product and process R&D

***1 chevron** = some uncertainty around timing of mass market adoption or phase out* ***2 chevrons** = considerable uncertainty around timing of mass market adoption or phase out*

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REVOLUTION 3

HYDROGEN INFRASTRUCTURE

- UK — 16 Hydrogen Refuelling Stations (HRS) & more on the way
- Europe/EU — 400 HRS in Germany alone by 2023 and 3700 HRS by 2030 over whole EU (FCH-JU)
- California — 50 HRS now and 1000 by 2030 (CFCP)
- China — 1000 HRS by 2030 & Billions of dollars (2016-2021) in subsidies for Hydrogen infrastructure and FCEV sales
- South Korea — 1000 HRS by 2030
- Japan — 1000 HRS by 2030

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REVOLUTION 4

FCEV TARGETS

- Europe/EU 1 million FCEVs by 2030 (FCH-JU (EU))
- California 1 million FCEVs by 2030 (CFCP)
- China 1 million FCEVs by 2030 (Chinese Government)
- South Korea 850,000 FCEVs by 2030 (Korean Government)
- Japan 800,000 FCEVs by 2030 (Japanese Government)
- Worldwide 80% buses FCEV (or BEV) by 2040 (BNEF)

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FUEL CELL EVs v BATTERY EVs 1

MORE GREEN

- **CLEANER ENERGY** — **Significantly less electricity production needed and so less emissions if using non-renewable sources**
- **LESS POLLUTION** — **No emissions at tailpipe and fuel cells act as mobile air filter**
- **LESS WASTE** — **Much less use of large batteries and scarce non-renewable resources (e.g. cobalt price tripling in the past two years)**

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FUEL CELL EVs v BATTERY EVs 2

MORE EFFICIENT

- **LESS WEIGHT** — Full hydrogen tanks weigh less than batteries or petrol/diesel, and overall, especially if combined with lean weight design, make FCEVs lighter and more efficient than either an ICEV or a BEV (up to 50% and 25% less weight respectively)
- **LESS VOLUME** — Hydrogen tanks take up less space than batteries meaning more of the vehicle space is usable for comfort and storage
- **MORE RANGE** — Currently FCEVs have ranges between 200-500 miles (300-800 km) on a single refuelling

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FUEL CELL EVs v BATTERY EVs 3

MORE CONVENIENT

- **ADAPTABLE** — 3 mins to fill a 2-5 kg tank (200 - 500 miles + 20 miles on battery alone) so quicker and less frequent than re-charging BEVs
- **SCALABLE** — Fuel Cells are increasingly being used in all transportation including bicycles, cars, trucks, buses, trains, boats, ships and even planes (45% of all flights leaving European airports are less than 500km – the range of current FC planes)
- **ACCESSIBLE** — Solar power and hydrogen make FCEVs a means of transportation to every corner of the world especially where there is no, or an unreliable, grid

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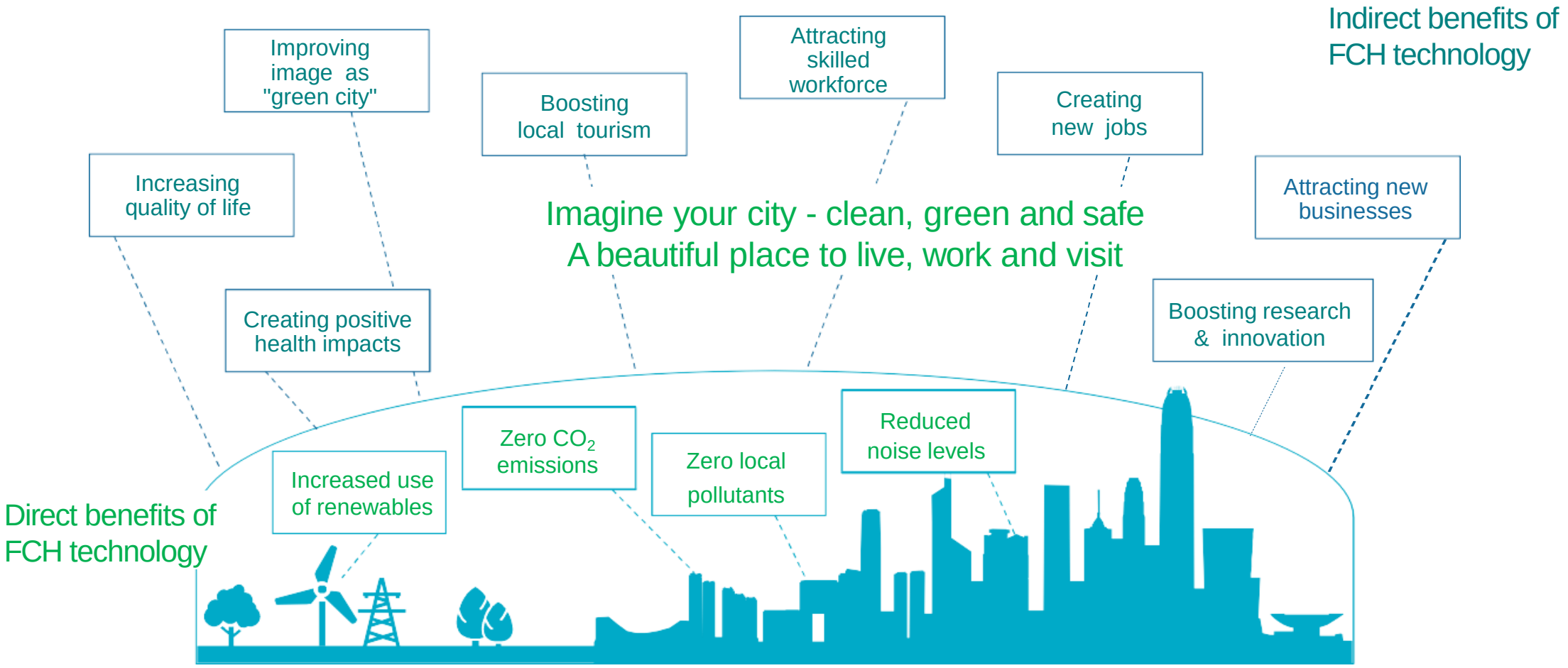
THE BENEFITS OF HYDROGEN/FUEL CELLS (FCH)



ARE FCEVs HAPPENING?

DOE: 1 fuel cell bus in US has exceeded the DOE/DOT target of 25,000 hours; more getting close, 25/1/19

One fuel cell electric bus (FCEB) operating in the United States has surpassed 29,000 hours of drive time and nine buses have exceeded 20,000 hours without major repairs or replacement of the fuel cell stack, according to the US Department of Energy (DOE). This is comparable to the life expectancy of a diesel engine in a transit bus.

Diesel buses have an engine that is sometimes rebuilt halfway through its usable life at 6 years/250,000 miles on average. The National Renewable Energy Laboratory (NREL) has collected data on fuel cell buses for more than 8 years.

https://www.greencarcongress.com/2019/01/20190125-fceb.html

World's first hydrogen fuel cell double decker buses in London from Wright Bus., 5/12/19

https://www.independent.co.uk/life-style/motoring/hydrogen-powered-buses-tfl-wrightbus-ryse-air-quality-a9220531.html 5/12/19

'Toyota Inside' strategy kicks off in China with fuel cells, 23/12/19

BEIJING -- Toyota Motor has begun supplying key components for fuel cell vehicles to other companies in China, seeking to emulate the way Intel came to dominate the microprocessor business as Taiwanese players built personal computers using its chips. Components being provided by the Japanese automaker include fuel cell stacks, which generate electricity through the chemical reaction between hydrogen and oxygen.

https://asia.nikkei.com/Business/Automobiles/Toyota-Inside-strategy-kicks-off-in-China-with-fuel-cells

China Sets Sights on Hydrogen Fuel Cell Market, 13/6/19

His vision to make China an electric-vehicle powerhouse revolutionized the global auto industry, cementing a move from the combustion engine. Now, Wan Gang says get ready for the next game-changing moment.

The world's biggest car market is set to embrace hydrogen fuel cell vehicles the way it did EVs, Wan, who's been called the father of China's electric-car movement, said in a rare interview in Beijing on June 9.

A former Audi executive who went on to become China's science and technology minister, Wan persuaded leaders two decades ago to bet on the then-untested technology of vehicle electrification, selling it not only as a way to boost economic growth but also to tackle China's dependence on oil imports and its mounting levels of pollution. His strategy — using government subsidies to bring carmakers and drivers on board — made China home to one of every two EVs sold globally today.

And now it's hydrogen's turn, Wan said.

https://www.ttnews.com/articles/china-sets-sights-hydrogen-fuel-cell-market

China sets sight on leapfrogging US and Japan in fuel-cell vehicles with subsidies for buyers and incentives for charging stations, 4/9/19

Buyers in 17 provinces will get subsidies of up to 160,000 yuan per fuel-cell vehicle this year while local authorities in 10 cities will hand out incentives of up to 4 million yuan toward the construction of every refuelling station

The Chinese government is aiming to put a million fuel-cell vehicles on the roads by 2030, from 50,000 in 2025 and last year's 1,791 units, more ambitious than plans outlined by Japan or in the US state of California

https://www.ttnews.com/articles/china-sets-sights-hydrogen-fuel-cell-market

WHAT ELSE IS HAPPENING WITH HYDROGEN?

Housing/Built Environment

Better Energy and Nilsson Energy develop world's first self-sufficient hydrogen housing complex, 30 homes, Vargarda, Sweden, 3/1/19

https://www.gasworld.com/worlds-first-self-sufficient-hydrogen-housing-complex-/2016206.article

Sweden, Housing Development Powered by Hydrogen Fuel Cells, 172 homes, 6 blocks, Vargarda, Sweden, Surplus electricity stored as Hydrogen and on TESVOLT TS 48V battery and then fed back in winter by 5kW fuel cell, 7/12/19

https://fuelcellsworks.com/news/sweden-housing-development-powered-by-hydrogen-fuel-cells/

Toyota unveils hydrogen-powered "city of the future", 7/1/20

https://www.h2-view.com/story/10012/?fbclid=IwAR3gh9kOSbsqlQzecX5kMVg_qHDIB28gUh88op8tBLgvSHJlqCXEILNKeIA

Japan is building the world's largest #hydrogen plant in #Fukushima as part of efforts to create a hydrogen-fueled society : 7/11/19

https://twitter.com/JapanGov/status/1192444078299832320

Heating and Cooking

Climate change hope for hydrogen fuel, 2/1/20

The natural gas supply at Keele University is being blended with 20% hydrogen in a trial that's of national significance. Adding the hydrogen will reduce the amount of CO2 that's being produced through heating and cooking. The 20% proportion was chosen because it's an optimal blend that won't affect gas pipes and appliances. The project – known as HyDeploy - is the UK's first live trial of hydrogen in a modern gas network. Keele was chosen because it has a private gas system.

The gas distribution firm Cadent, which is leading the project, says that if a 20% blend were to be rolled out across Britain, it would reduce emissions of CO2 by six million tonnes - equivalent to taking 2.5 million cars off the road.

Some boiler manufacturers are already producing prototype boilers that use 100% hydrogen. Worcester Bosch, for instance, has a "hydrogen-ready" design. It can run on natural gas, but it's capable of converting to 100% hydrogen following a one-hour visit by an engineer. The firm wants the government to stipulate that by 2025, all new boilers on sale should be hydrogen-ready.

https://www.bbc.co.uk/news/science-environment-50873047

Other Vehicles

Is Hydrogen The Fuel Of The Future For Climate-Friendly Flying? 11/12/19

ZeroAvia manufacturing powertrains and storage initially to power commercial planes for 20 passengers being carried 500 miles

https://www.forbes.com/sites/mikescott/2019/12/11/is-hydrogen-the-key-to-making-flying-zero-emission/#7af91faf7242

Hydrogen fuel cells becoming viable in maritime sector, 5/11/19

https://www.rivieramm.com/news-content-hub/news-content-hub/hydrogen-fuel-cells-becoming-viable-in-maritime-sector-56714

Schaeffler-Bio-Hybrid-Pedal-Powered-Light-Electric-Vehicle, 4/12/19

https://www.electrive.com/2019/12/04/schaeffler-bio-hybrid-pedal-powered-light-electric-vehicle/

Plug Power's stock soars on fuel cell contract win. 7/1/20

Shares of Plug Power Inc. soared in active trading Monday, after the hydrogen and fuel cell technology company announced a contract win valued at $172 million over two years from a large, unnamed company. The rally comes amid apparent renewed interest in fuel cell stocks, highlighted by the tripling in value of FuelCell Energy Inc.'s stock **FCEL, +1.37%** over the last four sessions of 2019.

https://www.marketwatch.com/story/plug-powers-stock-soars-on-fuel-cell-contract-win-2020-01-06

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Green and Blue (or grey or brown) Hydrogen manufacture

Project to turn biogas from sewage into renewable hydrogen and graphite wins ARENA backing

The Australian Renewable Energy Arena (ARENA) has approved up to $9.41 million in conditional funding to Hazer Group for the construction and operation of a groundbreaking hydrogen production facility in Munster, Western Australia. The project is utilizing biogas produced at the treatment plant as feedstock to produce hydrogen and graphite.

https://www.pv-magazine-australia.com/2019/09/02/project-to-turn-biogas-from-sewage-into-renewable-hydrogen-and-graphite-wins-arena-backing/

New Way to Make Hydrogen Energy Out of Water Much More Cheaply,

In research published in Nature Communications recently, scientists from UNSW Sydney, Griffith University and Swinburne University of Technology showed that capturing hydrogen by splitting it from oxygen in water can be achieved by using low-cost metals like iron and nickel as catalysts, which speed up this chemical reaction while requiring less energy, 9/1/20

Iron and nickel, which are found in abundance on Earth, would replace precious metals ruthenium, platinum, and iridium that up until now are regarded as benchmark catalysts in the ‘water-splitting’ process.

https://scitechdaily.com/new-way-to-make-hydrogen-energy-out-of-water-much-more-cheaply/

A bit of fun

U2 concert powered by hydrogen, 9/1/20

Four Toyota Mirai vehicles provided the power for a U2 concert in Tokyo, Japan last month, making U2 the first international touring band to use hydrogen power at a show. The bands guitar, bass and entire backline – guitar and bass amplifiers, audio effects and system control – ran entirely on clean hydrogen power. Parked backstage, the Toyota Mirai's stored the energy that delivered the power.

https://www.h2-view.com/story/u2-concert-powered-by-hydrogen/

New hydrogen Fuel Cell off-grid electric vehicle charger, 5/12/19

A British hydrogen company, AFC, has announced the launch of a new off-grid electric vehicle charger

https://www.motoringresearch.com/car-news/hydrogen-off-grid-electric-charging/

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What has this got to do with me (Fleets & Fleet Management)?

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Where's the Money?

China's 13th Five-Year Plan: Implications for Oil Markets, Oxford Institute for Energy Studies, June 2018

https://www.oxfordenergy.org/publications/chinas-13th-five-year-plan-implications-oil-markets/?v=79cba1185463

Hydrogen Council announces Deal, 5/12/19

The Hydrogen Council, a global initiative of CEOs representing energy, transport, and industry organisations advocating for the accelerated deployment of hydrogen solutions, and the European Investment Bank (EIB), one of the world's largest providers of climate finance, today signed a landmark agreement to collaborate on the development of innovative schemes to finance hydrogen projects to address climate change. Under this partnership delivered through the InnovFin Advisory program, EIB will provide strategic financial advice and support to companies preparing to deploy large-scale hydrogen projects, making such solutions more readily available to consumers around the world.

https://hydrogencouncil.com/en/eib-agreement/

EU Announce European Green Deal to solve climate crisis 11/12/19

https://www.theguardian.com/environment/2019/dec/11/european-green-deal-will-change-economy-to-solve-climate-crisis-says-eu

'Green hydrogen could be cheapest form of H2 within five years', IRENA, 12/1/20

https://www.rechargenews.com/transition/green-hydrogen-could-be-cheapest-form-of-h2-within-five-years/2-1-736269

Bank of England chief Mark Carney issues climate change warning. 30/12/19

Speaking to the Today programme, he re-iterated his warning that unless firms woke up to what he called the climate crisis, many of their assets would become worthless… "A question for every company, every financial institution, every asset manager, pension fund or insurer: what's your plan? …"Four to five years ago, only leading institutions had begun to think about these issues and could report on them. Now $120tn worth of balance sheets of banks and asset managers are wanting this disclosure [of investments in fossil fuels]. But it's not moving fast enough."

https://www.bbc.co.uk/news/business-50868717

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Stanford Researchers Have an Exciting Plan to Tackle The Climate Emergency Worldwide, 2/12/19

https://www.sciencealert.com/stanford-researchers-have-a-plan-to-tackle-the-climate-emergency

- **Impacts of Green New Deal Energy Plans on Grid Stability Costs, Jobs, Health and Climate in 143 Countries, Stanford University, 20/12/19**
- **Summary**
- Global warming, air pollution, and energy insecurity are three of the greatest problems facing humanity. To address these problems, we develop Green New Deal energy roadmaps for 143 countries. The roadmaps call for a 100% transition of all-purpose business-as-usual (BAU) energy to wind-water-solar (WWS) energy, efficiency, and storage by 2050 with at least 80% by 2030. Our studies on grid stability find that the countries, grouped into 24 regions, can match demand exactly from 2050 to 2052 with 100% WWS supply and storage. We also derive new cost metrics. Worldwide, WWS energy reduces end-use energy by 57.1%, aggregate private energy costs from $17.7 to $6.8 trillion/year (61%), and aggregate social (private plus health plus climate) costs from $76.1 to $6.8 trillion/year (91%) at a present value capital cost of ~$73 trillion. WWS energy creates 28.6 million more long-term, full-time jobs than BAU energy and needs only ~0.17% and ~0.48% of land for new footprint and spacing, respectively. Thus, WWS requires less energy, costs less, and creates more jobs than does BAU.
- https://www.cell.com/one-earth/fulltext/S2590-3322(19)30225-8

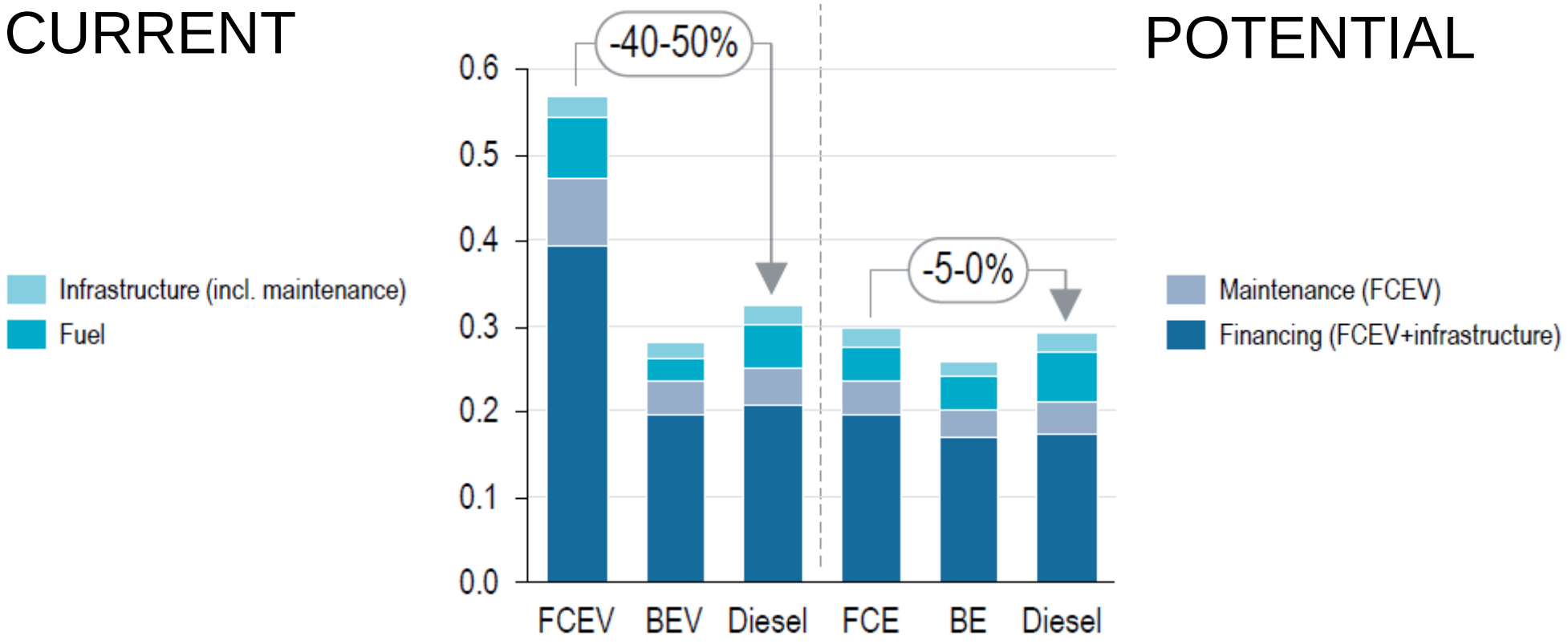
- **Impacts of *Green-New-Deal* Energy Plans on Grid Stability, Costs, Jobs, Health, and Climate in Europe**
- From *Jacobson, M.Z., M.A. Delucchi, M.A. Cameron, S.J. Coughlin, C. Hay, I.P. Manogaran, Y. Shu, and A.-K. von*
- *Krauland, Impacts of Green-New-Deal energy plans on grid stability, costs, jobs, health, and climate in 143*
- *countries, One Earth, 1, 449-463, doi:10.1016/j.oneear.2019.12.003, 2019,*
- https://web.stanford.edu/group/efmh/jacobson/Articles/I/WWS-50-USState-plans.html
- Summary
- The energy portion of the European *Green New Deal*
- • Costs $6.2 trillion upfront but pays for itself over time from energy sales
- • Costs include wind-water-solar (WWS) electricity, heat, H2 generation; electricity,
- heat, cold, H2 storage; short- and long-distance transmission; distribution
- • Creates 2.9 million more long-term, full-time jobs than lost
- • Saves 180,000 lives from air pollution each year
- • Eliminates European energy emissions affecting global warming
- • Reduces end-use energy requirements by 59.0%
- • Reduces private energy costs by 44% (from $2.08 to $0.67 trillion/yr)
- • Reduces energy, health, and climate costs by $1.4, $1.6, and $2.7 trillion/yr
- • Reduces social energy costs by 89% (from $6.39 to $0.67 trillion/yr)
- • Requires 0.19% of European land for footprint, 0.93% for spacing
- https://www.cell.com/one-earth/fulltext/S2590-3322(19)30225-8

PROJECTED FCEV COST REDUCTIONS

Estimated annualised total cost of ownership (TCO) [cent/km] - 2017 prices

CURRENT

POTENTIAL



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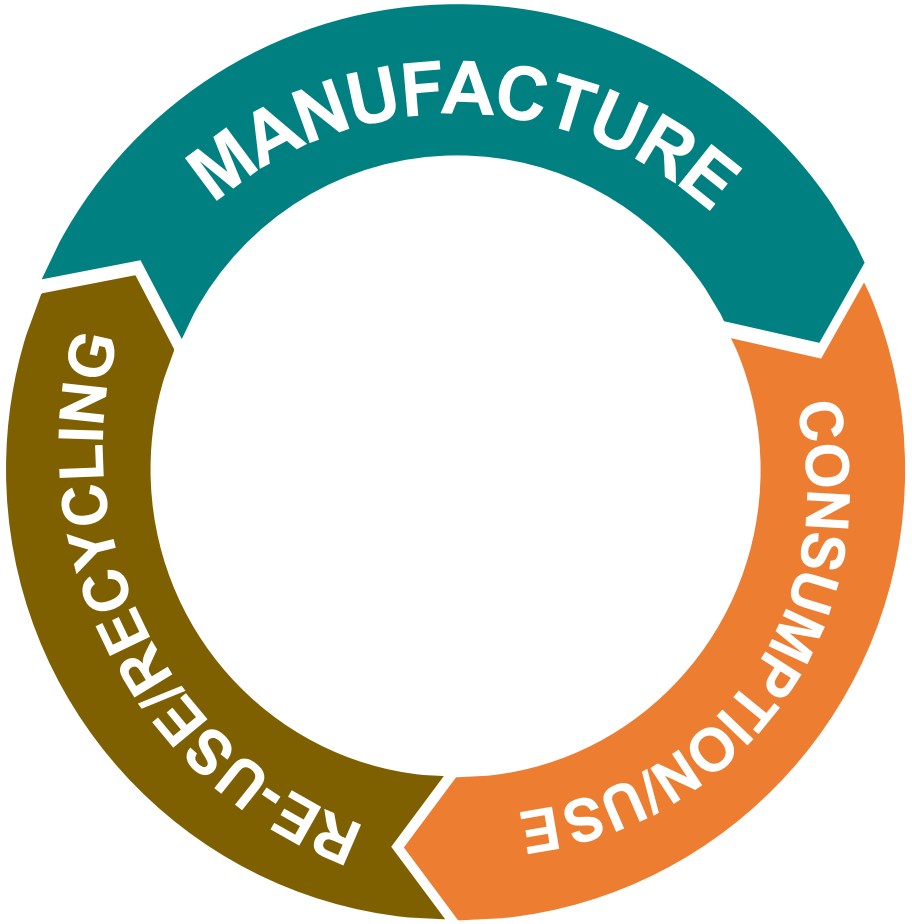
THE CIRCULAR ECONOMY



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CIRCULAR ECONOMY COST GAINS

- Re-usability — Vehicles made so parts/components can be reused or re-cycled
- Longevity — Vehicles last longer as part and components replaced over longer period, typically minimum of 10 years
- Maintenance — Will be part of sales/lease package to reduce costs
- Leases — Can be obtained over 10 years reducing monthly or annual cost
- Upgrades — Can be factored in to lease costs

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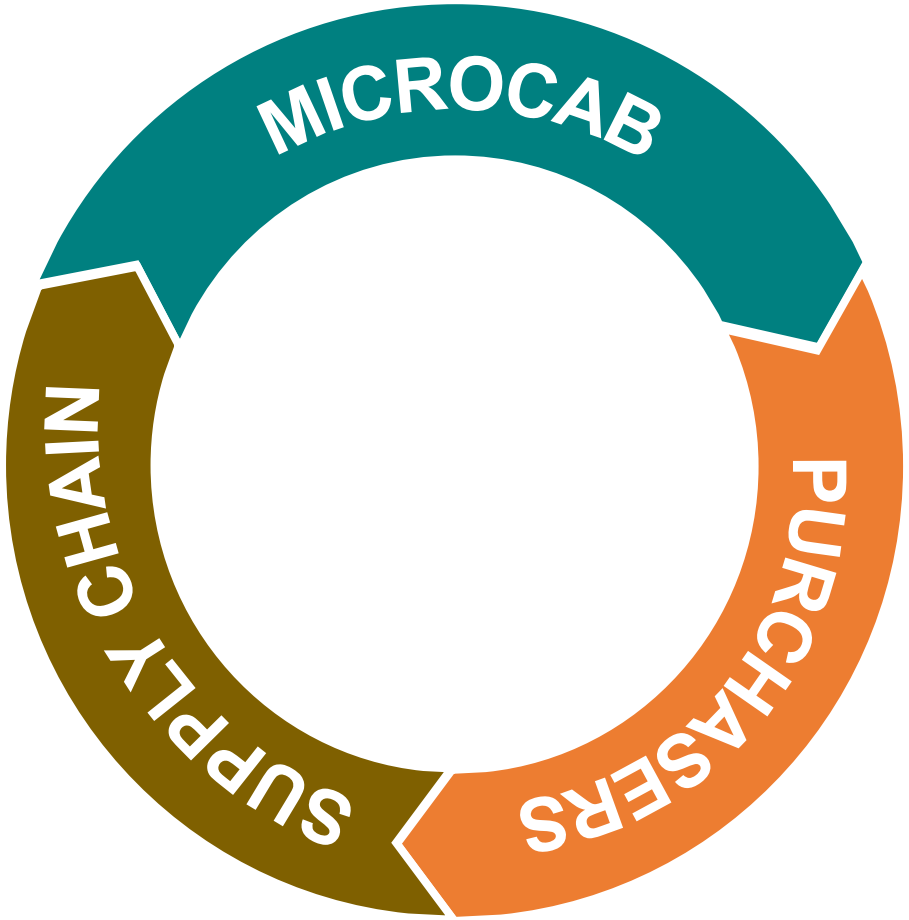
PRICE/COST CIRCULAR ECONOMY



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PROJECTED FCEV AND HYDROGEN COST REDUCTIONS

- Prices coming down all the time
- Rate of reduction increasing due to larger and larger deals
- Co-operation between purchasers, manufacturers and supply chains driving down costs (cf. FCH-JU and buses)
- Hydrogen fuel for vehicles projected to be less than petrol/diesel per km in three years
- With longer lasting vehicles lifetime of vehicles can be extended to 10 or even 20 years
- Longer lifetimes mean longer leases are possible meaning price/yr less
- TCO (Total Cost of Ownership) coming down all the time

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ARE THERE FCEV FLEETS HAPPENING?

- **Plug Power – Forklifts and local plant/vehicles**
- **Bus Fleets all over Europe, US, Japan, China and in the UK in London, Birmingham, Aberdeen and more to come…**
- **Main growth is in HGV/PSVs but Scotland and many UK/EU public authorities are very interested in fleet replacement generally and some last mile deliverers as well**
- **Will make a difference to how often fleet managers replace vehicles in 2020s and their lease structures**

ZEFER hydrogen fleet testing kicks off in London, 2/5/18
A project to test the capabilities of hydrogen-powered fleets across three European capitals gets underway in London this week.
https://www.theengineer.co.uk/zefer-hydrogen-fleet-london/

Green Tomato Cars covers one million miles on hydrogen, 23/10/19
The private hire company took on 25 Mirai after starting a trial with two cars in 2015. Building on this success, Green Tomato Cars has added a further 25 Mirai to its fleet this month, giving it the largest zero-emission passenger fleet in the UK.
https://www.fleetnews.co.uk/news/fleet-industry-news/2019/10/22/green-tomato-cars-cover-one-million-miles-on-hydrogen

MET POLICE GOES ZERO-EMISSION WITH FLEET OF TOYOTA MIRAI HYDROGEN CARS, 14/3/18
LONDON'S Metropolitan Police Service has added the first-ever "zero-emission" cars to its fleet: 11 Toyota Mirai hydrogen fuel cell cars.
https://www.driving.co.uk/news/met-police-goes-zero-emission-fleet-toyota-mirai-hydrogen-fuel-cell/

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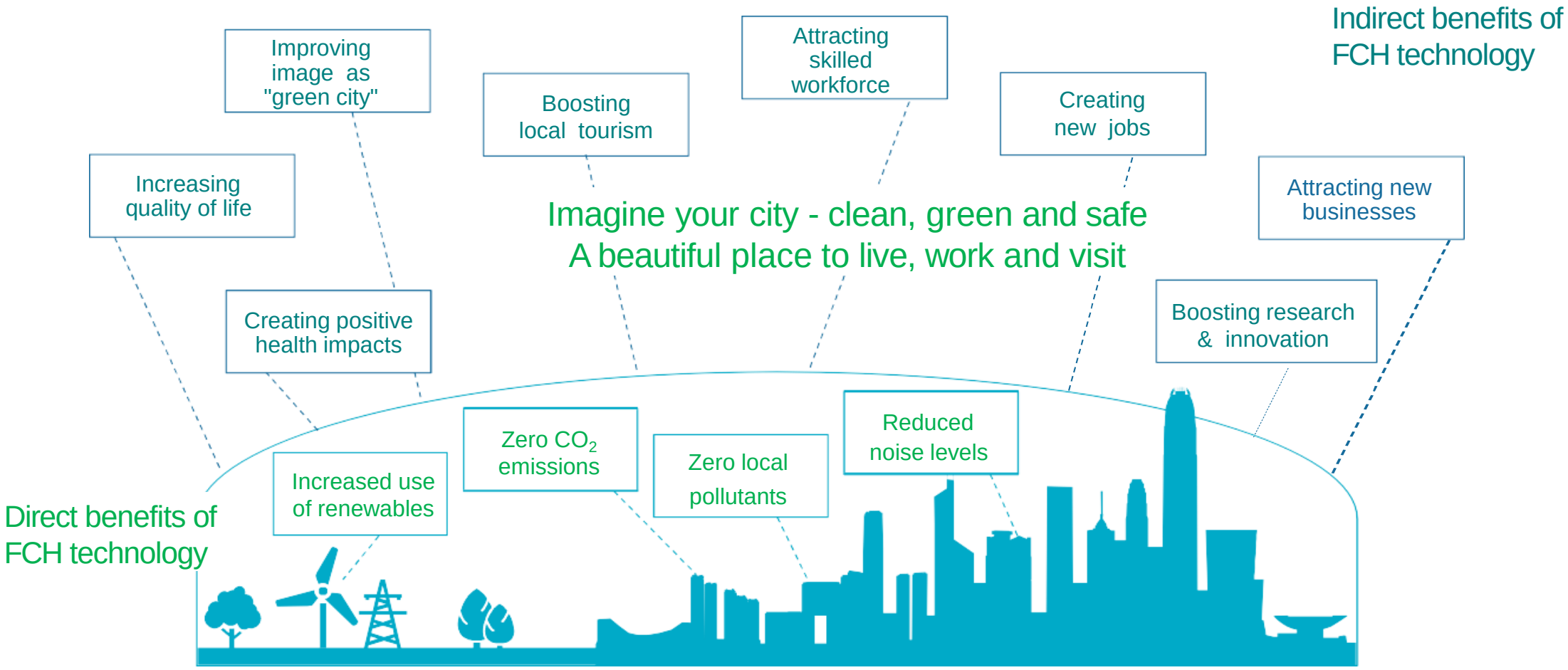
THE BENEFITS OF HYDROGEN/FUEL CELLS (FCH)



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